Pima County Hydrology Comments

04-18-17

1. **Davidson Canyon is an Important Intermittent and Perennial Water Resource**
    a. Perennial conditions throughout the 1990s and early 2000s
    b. Currently intermittent, as evidenced by wet/dry mapping and wetland indicator plants.

2. **Consultant Models that account for amounts and timing of water inputs are inadequate**
    a. The assessment conducted for Rosemont underestimated downstream flows by using underestimated annual rainfall.
    b. The modeling method used is inadequate to evaluate intermittent flows.
    c. A model capable of evaluating temporal change is necessary for evaluations, such as the watershed diversions that occur in first 10 years of mine operations.
    d. Models capable of evaluating temporal change on daily and monthly timesteps have already been applied to this watershed
    e. Isotopic data suggests a winter, higher elevation source for water in Davidson Canyon and Cienega Creek.

3. **Water quality and quantity issues at the mine site have not been addressed**
    a. Water quality issues:
        i. Agencies have not examined WQ consequences, including altered rates of loading, infiltration and assimilation
        ii. 401 certification considers post-dredging period as baseline
        iii. Capacity of dam will be exceeded frequently
        iv. Will uncontrolled releases of contact water meet Arizona Surface Water Quality standards, including suspended solids?
        v. No analysis of impacts of retaining this runoff
            1. Increased contact and potential for water quality impacts
        vi. 65 million tons of Cu oxide-bearing rocks in waste rock (exceedances already noted by SWCA)
        vii. Agencies have not considered practicable alternatives to the proposed discharge of oxides to WUS
        viii. Seepage
            1. FEIS did not correct hydraulic conductivity, precip or ET used in seepage analysis
            2. Ignores preferential flow paths
            3. Ignores 65 million tons of Cu oxide-bearing rocks
        ix. 401 Baseline
            1. ADEQ improperly approved a definition requiring water quality after construction impacts to be deemed natural variation
            2. Samples taken after mine diversions and land clearing impacts would be considered part of the baseline
            3. No mitigation of water quality impacts would be required under this definition
    b. Water quantity issues:
        i. Perimeter containments could be drained to reduce impacts
        1. Unnecessary reduction of flows to Barrel and Davidson

Excerpt from Pima County's April 2014 401 Comments

The well is located downstream and outside reach 2. Observations of groundwater levels at the well do not represent conditions at the reach 2 spring. The 2005 PAG report identifies several reaches of Davidson Canyon as having perennial and intermittent flow based on PAG observations, independent of the Sky Island Alliance data.

Seepage to Waters of the US and Seepage Monitoring

Page 5 and 6 of ADEQ's Basis refers to the potential for seepage from the waste rock and tailings piles to Waters of US. Pima County and Pima County Regional Flood Control District have objected to the inadequacy of the EIS with respect to seepage and seepage monitoring. The Forest Service is the process of reviewing objections. One objection is that the FEIS modeling of waste rock seepage is faulty. Another objection is that FEIS ignores the high probability of preferential seepage flow in the tailings and waste rock piles. A third objection is that the FEIS waste rock seepage monitoring plan will not result in adequate seepage impact evaluation .

Objection: The modeling of waste rock seepage is faulty.

The EIS must justify the parameters used and complete a sensitivity analysis of the parameters to demonstrate that the results of the seepage modeling are feasible; this is especially needed since there is no data to calibrate to. They must also justify ignoring preferential flow paths through the waste rock. The mine facility seepage analysis predicts there will be essentially no seepage through waste rock facilities, a result that is simply not feasible. The modeling used parameters in which the conductivity for relatively dry rock is six orders of magnitude less than when saturated. These parameters would allow a wetting front to move through unsaturated waste rock only very slowly; even most of a large event would be stored in the top few feet. After the storm ends, the close proximity of most of the seepage to the ground surface would allow the water to be evaporated away because evaporation would quickly establish an upward matric potential gradient.

The EIS repeats this error, which affects the quality of the organic constituent analyses. It does not seem reasonable that infiltration from waste rock be close to zero because natural recharge in this area is not zero. Blasted waste rock is almost certainly more conductive than the in-situ rock. It is also unlikely that the onefoot thick cover will result in less infiltration than the natural soil and vegetation regime.

Similarly, it is not reasonable for the seepage through a leach pad to cease. Leach pads are designed to conduct flow. All water that gets through the cover will become seepage. Based on experience, the long-term seepage through heaps in more arid climates in Nevada do not approach rates as experience has shown that waste rock dumps in much drier climates will have seepage.

These three comments refer to the estimates of infiltration through waste rock, which have been estimated to be near zero. These comments had been made without reviewing the waste rock seepage study.

The modeling is effectively water balance modeling among layers in the facility, with [f]low between layers controlled by unsaturated flow equations, or saturated in areas where saturation occurs. Unsaturated flow modeling solves the equations of soil physics, most specifically the flow equation relating the matric potential gradient to the conductivity, which varies as a function of matric potential. Unsaturated flow is toward the lower matric potential which occurs at the point where the media is drier, all other conditions being equal. When saturated the equation becomes Darcy's law and the matric potential gradient becomes the head gradient. Matric potential becomes negative as soil dries, so during dry conditions water from depth can be drawn to the surface and evaporated in a process known as exfiltration.

Tetra Tech utilized a two-dimensional variably saturated flow model, VADOSE/W, for this simulation (Tetra Tech 2010c, p. 20). The code solves the flow equations using a finite element routine. Two-dimensional means flow in a vertical cross section. Tetra Tech emphasizes that it "can simulate heterogeneous material, and can account for changes in material conditions due to compaction and underlying alluvial and/or bedrock formations" (Id.). This simply means that different model elements may be defined by different material property parameters and that those parameters can represent any material including compacted waste rock. The modeling presented in this Tetra Tech study is strictly based on conceptual flow models for the various materials because there are no data to which to calibrate. Material parameters depend on textbook or smallscale test values. The predicted values are not verified in any way to previously observed data.

The model simulates precipitation and evaporation, using various sequences of climate data for the simulations. Climate data provides the daily precipitation, temperature, wind speed, and evaporation. Using data from the Nogales site (Tetra Tech 2010c, p. 21) is not unreasonable, but the scenario using average daily values is not representative. TT states that the average conditions "dataset has small amounts of precipitation everyday because of the averaging of many years of data" (Id.) and call this "conservative". In a response to a review memorandum, TT (2011) responded that "[t]he average conditions dataset, as noted in previous memos, has precipitation nearly every day of the year. This is not likely to occur in Arizona, but would be a worst case scenario. Water is more likely to readily infiltrate into a facility if the upper surface is wet, so considering a climate conditions with a small amount of precipitation each day would produce such a condition and provide a result of the worst case infiltration" (TT, 2011, p. 2, emphasis added). Tetra Tech apparently considers this to be conservative, but the evaporation likely exceeds precipitation most days so there would rarely be an excess of precipitation to infiltrate. Even during winter, average precipitation may exceed the average evaporation by only a small amount, but the model would accumulate moisture in the top layers. This modeled soil moisture may just be stored and later evaporated as conditions warm and dry in the spring. Infiltration through the surface zone would occur when moist antecedent conditions precede a large daily rainfall; this type of situation which would result in seepage has been ignored in the Tetra Tech study. This is not uncommon during late winter or spring snow melt and subsequent spring showers.

The mine development periods and reclamation scenarios simulated are reasonable (TT, p. 22). Whether the parameters used for the scenarios were proper remains a question.

Tetra Tech discusses steady state modeling as a means of determining starting moisture concentrations for the transient simulations (Tetra Tech 2010c, p 37). In a system that should be event driven, steady state should never be approached, much less achieved.

The assumed parameters for the waste rock control the seepage through the waste rock facilities. The so-called permeability reported by Tetra Tech is actually saturated hydraulic conductivity (K). The values are very high, but the unsaturated values decrease very rapidly.

The figures showing the relationship of conductivity with matric suction and moisture with matric suction are poorly labeled. For example, Illustration 5.6 shows the relations for run-of-mine (ROM) rock, with saturated K equal to 174 ft/hr; the matric suction on the conductivity graph does not obviously match the axis for the moisture content, and does not have labels. Even the conductivity axis does not have labels for ROM rock.

Considering Ill 5.7 for semi-consolidated rock, the conductivity decreases over five orders of magnitude from saturated to dry (moisture 0.4 to 0.05). At the beginning of a storm with dry antecedent conditions, infiltrating precipitation increases the moisture content which increases the effective conductivity. As noted, the parameters for the surface ROM layer are hard to read, but dry (moisture about 0.16), the conductivity is significantly less than 174 ft/hr. Assuming no runoff, the ROM would rapidly saturate at a wetting front. Because of the low conductivity the wetting front would advance very slowly with conditions above the front being saturated. This means that significant amounts of ROM above a wetting front would be saturated. According to Ill 5.6, the difference between saturated and dry moisture content is the difference between 0.27 and 0.18, or about 0.09. Using these numbers, a three-inch infiltration event would be completely stored in just 33 inches of initially dry ROM, based on the available porosity between 0.18 and 0.27 being 0.09. The modeling assumes that it completely fills. Once the infiltration event ends, water would continue to seep downward, drawn by gravity and a negative matric potential. However, evaporation would begin at the upper end and, as the surface soil dries, a negative matric potential would develop on the surface and begin to counter the downward movement of the stored water.

The example just given allows the soil above the wetting front to become saturated because of the large difference in effective conductivity at the wetting front, which keeps the water close enough to the ground surface for evaporation to begin to quickly remove the water after the precipitation event ends. During summer, when the larger short duration events are most likely, the daily potential evaporation is as much as half an inch per day which means that most of the precipitation stored in upper layers of the waste rock would quickly evaporate; it is clear why the modeling does not simulate deeper seepage of water.

The figures showing water content through a model cross-section are clear (Ill 5.15 and 5.16). Near the surface, the moisture content is about 0.1 which increases initially with depth to about 0.14 but then decreases to 0.04 in the consolidated zone. This moisture content is less than the lowest moisture content presented in Illustration 5.8 for consolidated material, so the accuracy of the data is questionable. Clearly the effective conductivity at that moisture is 10-7 ft/hr (2.4x10-6 ft/d), an almost negligible conductivity.

The effective gradient due to high negative matric potential may be significantly higher than 1. Even at 1000, the water would move only about 2.4x10-3 feet in a day. These numbers should make clear why the model does not simulate seepage through the waste rock. The small amount of moisture below the unconsolidated ROM can be simulated to move only very slowly. These numbers suggest that increasing the moisture available significantly would not result in substantial differences in moisture content at depth, meaning that whether the model considers runoff accumulating at a location is irrelevant.

Many of the water balance figures, such as Illustrations 5.12 and 5.14, show precipitation entering the system and evaporation leaving the system; because the evaporation exceeds the precipitation, water leaves storage so that the moisture content decreases. These figures present a year's results, but presumably the waste rock would just become drier with time and evaporation would have to approach precipitation as stored water available to evaporate would dissipate. The figures also demonstrate that the model simulate almost no runoff.

The modeling does not account for preferential flow which can allow flow to move quickly through the piled waste rock. A preferential flow path in a waste rock dump is a pathway of larger pore spaces through which groundwater flow tends to funnel; it is similar to flow through fractures in in-situ bedrock. By ignoring preferential flow, the model underestimates seepage through any of the mine components, although waste rock would likely be most heterogeneous.

Tetra Tech's mention of preferential flow (TT, p. 20) refers to the fact that hydraulic conductivity for unsaturated flow varies with moisture content; different materials are preferentially more conductive at different moisture contents. More flow occurs through clay at low matric potential than through coarser sand because the sand is actually drier. The curves in TT Figure 5.5 may apply in a given facility but they would not apply at the same point (due to differing soil types at each point) so the flow cannot transition from on to the other.

The FEIS reports results from modeling seepage through waste rock dumps that are unreasonably low. This is because the modeler used unrealistic unsaturated parameters and used climate data from the wrong location.

The FEIS responded to comments by having Rosemont consider additional scenarios. The scenarios had to do with the length of simulation but with inappropriate climate values the antecedent conditions were never wet enough to allow additional seepage beyond the surface. The FEIS did not amend or address the fact that the precipitation data was wrong and the ET data was from Tucson. The presence of seepage through waste rock all over the country including in areas much drier than Rosemont demonstrates that seepage can occur.

The FEIS also does not respond to the comment about the wrong hydraulic parameters for the soil – specifically that the unsaturated conductivity was incredibly low which prevented any water entry to the waste. The FEIS did not address these problems or have Rosemont test the sensitivity of the waste rock parameters in their model

Conclusion and Recommendations

- **The EIS must present data justifying the conductivity parameters.** It is not reasonable for ROM rock with saturated K = 170 ft/hr to only allow seepage to move a few feet before being removed by exfiltration.
- **The study should be redone to include a sensitivity analysis.**

If the conductivity for high matric potential rock is set higher and there is still no seepage, then the EIS may be able to conclude there is no seepage. Otherwise, the results of this seepage study are simply uncalibrated estimates based on very unrealistic parameters.

<u>Objection: The FEIS ignores the high probability of preferential seepage flow in the tailings and waste rock piles</u>

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demonstrate that the results of the seepage modeling are feasible; this is especially needed since there is no data to calibrate to. They must also justify ignoring preferential flow paths through the waste rock. The mine facility seepage analysis predicts there will be essentially no seepage through waste rock facilities, a result that is simply not feasible. The modeling used parameters in which the conductivity for relatively dry rock is six orders of magnitude less than when saturated. These parameters would allow a wetting front to move through unsaturated waste rock only very slowly; even most of a large event would be stored in the top few feet. After the storm ends, the close proximity of most of the seepage to the ground surface would allow the water to be evaporated away because evaporation would quickly establish an upward matric potential gradient.

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>
> FEIS claims that seepage would not be concentrated but would rather be spread across the entire area of the facility. The FS rejects good science and observations at literally every waste rock seep showing that seepage discharges from a point, not spread around the base of the facility.
>
> Preferential flow would cause seepage through waste rock (and tails) to reach the ground surface at concentrated locations rather than spread over the entire area of the facility. This is unaccounted for in the modeling and the FEIS in general. Because preferential flow has the potential to significantly impact downstream waters and habitats, the models should be re-run to account for this phenomenon.

<u>Objection: The FEIS waste rock seepage monitoring plan will not result in adequate seepage impact evaluation .</u>

The monitoring plan calls for two points to be monitored for moisture content. The waste rock dumps cover a large area, but the FEIS suggests there will be no seepage. Objection 7 deals with the high probability of preferential flow in the piles, which means that actual seepage will likely be concentrated. The mitigation plan in the FEIS calls for monitoring seepage in just two locations. Because preferential flowpaths could develop almost anywhere, there is little chance that the proposed monitoring will actually detect seepage if it occurs.

ADEQ's Basis states that "should the seepage reach surface waters, an individual AZPDES permit would be required and discharges would have to meet the appropriate surface water quality standards individual antidegradation." However, neither ADEQ nor Forest Service have provided for monitoring to detect seepage that has reached surface waters, except if the seepage reaches the compliance point dams. ADEQ should require detection and reporting of any inadevertently created surface water features created in and around the mine site upstream of the Barrel Canyon compliance dam. Detections should trigger monitoring to assure that any unplanned water bodies are meeting state water quality standards.